Coal Conversion Plant Cost Escalation

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Coal conversion plants are capital intensive. At least half the price of coal-derived synthetic fuels arise from fixed charges (1) and the cost of commercial-sized plants are such that capital availability is a major problem. Thus, economic evaluations of coal conversion processes are strongly influenced by the capital cost estimates used. Further, these estimates in recent years have been subject to substantial escalation due to inflation. Also, the long periods of planning and construction required for coal conversion plants compounds both the effects of escalation and interest during construction.

Since escalation heavily impacts coal conversion economics, a study was undertaken for ERDA to: 1. Identify and quantify factors contributing to the recent escalation of coal-based fuel plant cost estimates. 2. Identify indices which in the past have best reflected inflation escalation of coal conversion plants, and 3. Suggest procedures for predicting future capital cost escalation.

Escalation analysis requires at least two cost estimates of the same plant made at different times. Preferably there should be several sets of estimates for several plants all using the same process and having about the same capacity. The only available sets of estimates meeting the above requirements were cost estimates for the Lurgi coal gasification process. These estimates were particularly valuable since they were based on common design data supplied by the Lurgi Corp. In addition, the three sets of estimates used were associated with plants which all used Western sub-bituminous coal to produce from 250 to 288 million SCFD of pipeline grade gas per stream day.

Prior to the main analysis, the applicability of Lurgi results to other gasification processes was checked by comparing Lurgi escalation data with estimated escalation for several advanced gasification processes under comparable conditions. These data derived from (2) and (3) are tabulated below.

Process	Aug. '74 Cost, $MM	Jan. '76 Cost, $MM	% Increase
IGT Hygas	750	870	16
CO_2 Acceptor	760	890	17
BCR Bi-Gas	890	1,030	16
Lurgi	920	1,060	15

From the above, it appears that Lurgi escalation data can be extrapolated to advanced pipeline grade coal gasification processes.

Low and medium Btu gas projects present a special problem since each plant is

designed to meet a particular customer's demand. (Typically, capacities vary from 21 to 100 trillion Btu [year].) However, since the reactor and purification steps of the low Btu processes are similar to those of the Lurgi processes, there appears to be no a priori reason why escalation for pipeline grade gas should be markedly different from escalation for lower grade gas processes.

Coal liquefaction presented another problem. Aside from methanol (around 85 percent of the Lurgi and methanol processes capital costs are for common equipment), liquefaction and gasification processes do not have a high degree of equipment commonality. Consequently, the approach taken was to perform the analysis outlined below and then check the main results with experts in coal liquefaction technology. In brief, the results for inflation escalation did check fairly well.

Lurgi cost estimates were collected and then normalized to place them on as comparable basis as possible. The normalized data were then disaggregated into the components of escalation that arise from: 1. Changes in the type of estimate. 2. Changes in knowledge of technology and environmental requirements. 3. Changes in equipment capacity, and 4. Changes in the costs of equipment, materials and labor (inflation escalation).

The inflation component of escalation was then compared by statistical tests and other means with various cost indices. Then, based on certain criteria, those indices best reflecting estimated Lurgi escalation were identified. The results and implications were analyzed and, finally, methods for predicting future escalation were suggested.

Five organizations generously cooperated in the collection and analysis of the estimates. These were, El Paso Natural Gas Co., Panhandle Eastern Pipeline Co., Southern California Gas Co., The Fluor Corp. and the Lummus Corp. To protect the privacy of the estimates, results are identified only as venture A, B or C.

The component of escalation due to estimate type was first examined. This component could arise because a prudent venture manager might require that a contingency adjustment equal to the upper bound of the accuracy range of the pertinent type of estimate be included in project costs. However, none of the estimates obtained had to be adjusted for estimate type because all of the estimates were "preliminary" (about $\pm$ 20% probable accuracy) and all contingency costs were removed when the estimates were normalized.

After removal of contingency, interest during construction and certain project specific costs (e.g., coal mine and sales tax costs) the following breakout of escalation for the ventures was obtained.

Lurgi Escalation Results

Venture	Escalation						
	Sept. '72-July '73		July '73-Jan. '75		Jan. '75-Early '76		Comments
	Tech. %	Inflation %	Tech. %	Inflation %	Tech. %	Inflation %	
A	38	6	34	56	-	-	Tech. escalation did not include design.
B			38	57	8	20 (Jan.)	Tech. escalation includes design changes.
C			N. A.	60	N. A.	16 (Apr.)	Estimates adjusted to remove technology and design change escalation.

Note that estimates were in constant dollars as of estimate date, i. e., no forward escalation.

There are four indices that are commonly used to track inflation escalation. These are the Chemical Engineering (CE), Marshall & Swift (M&S), the Nelson index of refinery costs (Nelson) and the Engineering News Record (ENR) indices. Also, coal-fired power generation boiler plant equipment escalation as given by the privately circulated Handy & Whitman (H&W) index was thought pertinent.

The five indices identified above are based on weighted averages of labor, material and equipment costs. But it was suspected that the traditional weighted-average indices understate the importance of equipment prices during periods of high inflation such as those experienced between mid '73 and early '75. Consequently, two pure equipment indices were also compared to the Lurgi data. These were the Nelson equipment index (a composite of five equipment classes) and an index of valve and fitting prices which was the only single item index that matched Lurgi escalation reasonably well. The results of the comparison are tabulated below.

Comparison of Lurgi and Cost Indices Inflation

Escalation

Category	Escalation		
	Sept. '72-July '73 %	July '73-Jan. '75 %	Jan. '75-Early '76 %
Lurgi	6 (1)*	56-60 (3)*	16-20 (2)*
Chemical Engineering (CE)	5	24	4
Marshall & Swift (M&S)	2.5	28	5
Nelson Refineries	5	19	7
Engr. News Record (ENR)	8.5	11	9
Handy & Whitman (H&W)	6	37	9
Nelson Equipment	4	38	8
BLS Valves & Fittings	5	51	6

* Numbers in parentheses indicate number of observations.

Since the Lurgi estimates only covered about four years, it was thought desirable to select a process which might exhibit about the same inflation escalation as a Lurgi process and where data was sufficient to permit development of an index for a number of years. The ethylene cracking process was selected for the following reasons: 1. Both Lurgi and ethylene plants are reasonably similar from the standpoint of scaling factors. 2. The front end of a Lurgi plant includes a number of identical gasifiers; the front end of an ethylene plant includes a number of identical cracking furnaces. 3. Both types of plants have either single or dual purification systems and substantive compression equipment. Also, they require closely integrated utility systems. 4. Escalation for the ethylene index for 1973-1975 was 67 percent vs. 55-60 percent for Lurgi from mid-1973 to 1975.

The processes are different in that gasification plants have provision for extensive solid handling facilities for coal feed and ash removal. But, for other reasons, coal preparation and handling costs were backed out of the estimate during the normalization procedure.

The ethylene index was used as follows. The coefficient of correlation "r" between the rates of change of the ethylene (Lurgi analog) index and the other indices were computed. Rates of change were used to reduce the autocorrelation between successive values of an index. The "r" values were then used as one criterion for selection of a representative index. The other criterion was closeness of fit to gasification escalation during the critical inflation period of mid '73 to early '75. The evaluation results are shown below.

Index Evaluation Results

Index	Escalation from July '73-Jan. '75 %	Correlation Relative to Ethylene 1965-1975 "R"*	1970-1975 "R"**
Lurgi Plants	56-60	N. A.	N. A.
Ethylene Plants	N. A.	1.000	1.000
CE	24	0.828	0.758
M&S	28	0.736	0.636
ENR	11	-0.134	-0.754
Nelson	19	0.491	0.152
Nelson Equipment	38	0.814	0.759
H&W	37	0.735	0.627
Valves	51	0.715	0.708

*R > | .625 | Significant at > .95 Level

**R > | .811 | Significant at > .95 Level

The results are also illustrated in Figures 1 and 2. Figure 1 shows the rates of change of three representative indices and the ethylene index, while Figure 2 shows the actual ethylene values vs. values predicted from the three indices. The predicted values were obtained by first regressing ethylene values on the indicated indices to obtain linear equations with relative ethylene costs as the dependent variables. Then, actual values of the appropriate indices were inserted into the equations to generate the prediction curves in Figure 2. All predicted values underestimate inflation in 1974, and then overcompensate in 1975.

The results obtained for the Lurgi process were then reviewed with experts in coal liquefaction. What was learned is summarized below.

	Lurgi/Ethylene Data	Coal Liquefaction Data
Technology Escalation	85% for Lurgi, Sept. '72 to Jan. '75	15% over 4 years
Inflation Escalation	195% Mid '70-Mid '75, C_2H_4 55-60% Mid '73-Early '75, Lurgi	250% Mid '70-Mid '75 Lurgi escalation "in the ball park" for liquefaction.

It was concluded that the high Lurgi process technology escalation is not typical of other coal conversion processes in that: 1. A World War II period design had to be adapted to modern materials and fabrication techniques. 2. The downstream design (purification, shift and methanation) had to be adapted to larger capacities than originally specified. 3. The design had to be adapted to U.S. codes and environmental regulations. The implication of this conclusion is that aggregated cost data such as that presented in Lurgi ventures to the FPC may

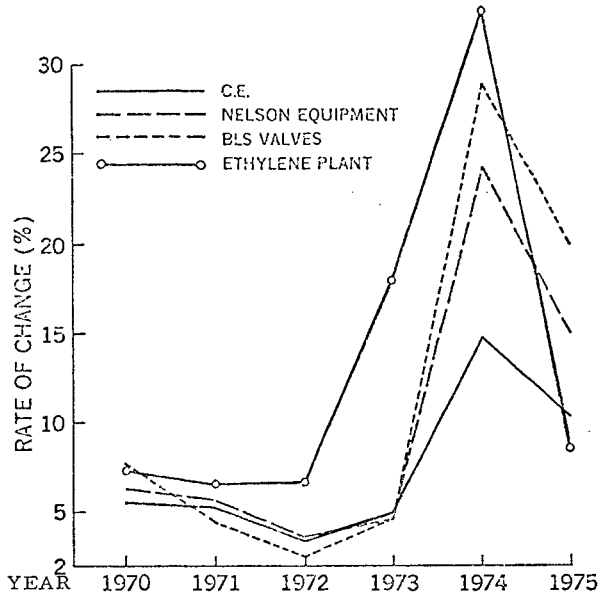

Figure 1. RATE OF CHANGE VS. YEAR

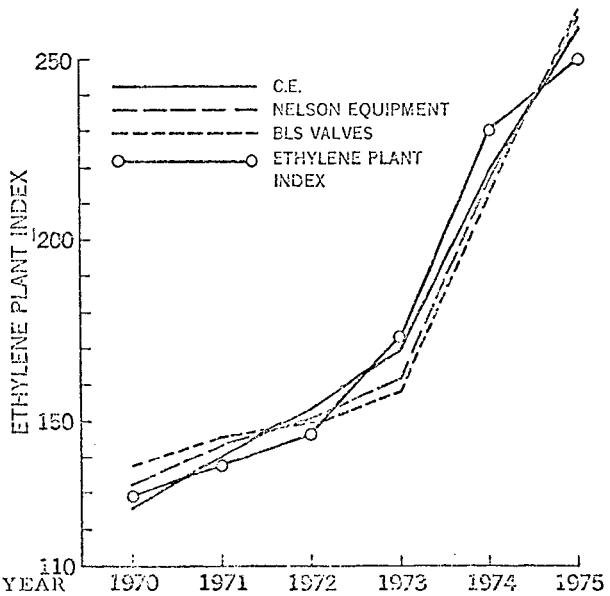

Figure 2. PREDICTED INDEX VALUES VS. YEAR

exaggerate the amount of escalation that might be experienced by advanced coal conversion processes.

On the other hand, it was concluded that the inflation escalation estimated for the Lurgi process was generally applicable to other coal-based synthetic fuel processes. Using the criterion of fit to high inflation periods, the index for valves was judged to best reflect the inflation escalation experienced in the critical 1973-1974 period. Using the correlation coefficient criterion, either the CE or Nelson equipment index was judged "best".

It was also concluded that an equipment type index tracks escalation during periods of high inflation better than do the weighted-average indices. (Note the CE index is weighted 61 percent for equipments vs. 12 percent for the Nelson index vs. 0 percent for the ENR index.)

Methods suggested for predicting future escalation included the following:

- Correlate certain representative indices (e.g., as tentatively identified above) with exogeneous indicators by econometric methods. Forecasts of the indicators are available from such services as DRI, Chase and Wharton.
- Survey the larger constructor/engineers for 2-4 year trend forecasts on equipment, material and labor costs pertinent to coal conversion plants.
- Survey a cross-section of process equipment manufacturers to obtain detailed cost trends.

References

1. Synthetic Fuels Commercialization Program, Volume III, Chapter I, by Synfuels Interagency Task Force for the President's Energy Resources Council, November 1975.

2. Excerpt from Report 4568-109-0932 to the American Gas Association, entitled "Coal Gasification Rough Estimate - Western Coal Plant Capital and Operating Costs, Gas Costs 250 x 10^9 Btu/Day Plant," August 1974.

3. Preliminary Economic Comparison of Six Processes for Pipeline Gas From Coal, by Roger Detman, C. F. Braun & Company, October 1976. Presented at the 8th Synthetic Pipeline Gas Symposium.